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TECHNICAL
PUBLICATION

NATIONAL PHOTOGRAPHIC
INTERPRETATION CENTER

EVALUATION OF CONVENTIONAL/NONCONVENTIONAL FILMS

25X1

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NPIC/R-42/71

MAY 1972

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NOTICE

This document constitutes one-half of a two-part study (see AFSPPF Special Report 101-1-151, Westover AFB). The National Photographic Interpretation Center (NPIC) and the U.S. Air Force Special Projects Production Facility (AFSPPF), Westover AFB, were tasked by the Configuration Change Board (CCB) to conduct an analysis of reproduction products. The CCB specified the products to be tested and the original negative materials to be used in generating the test samples. The films (reproduction materials) tested [redacted] 25X1

25X1 [redacted]

The NPIC test design was three-part: (1) Photointerpretation, (2) Mensuration (subdivided into measures of pointing accuracy and pointing repeatability), and (3) Technical (subdivided into resolution target analysis and overall quality comparison). The AFSPPF test was conducted in five parts: (1) Characterization Studies, (2) Printing/Processing, (3) Bar Target Resolution Analysis, (4) Photointerpretation Quality Appraisal, and (5) Microdensitometric Line Target Analysis.

There was a significant difference between NPIC and AFSPPF only in the resolution ranking of the duplication films. Average resolution calculations by NPIC resulted in a lower ranking of the Reduced Silver and Free Radical materials. These materials were ranked considerably higher in the AFSPPF resolution analyses. This difference is attributed to resolution reader variability and target reading technique used by each organization.

The basic conclusions derived by both organizations were similar. In overall rankings that encompassed all analysis procedures [redacted] was preferred to all duplication films. While NPIC ranked viscous-processed [redacted] first, AFSPPF found spray-processed [redacted] to be best. Neither organization found significant difference between these films. The remaining duplication materials were ranked identically [redacted]

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[redacted]
25X1

INTRODUCTION

The National Photographic Interpretation Center has evaluated six duplicating films for their overall duplicating potential of large volume, roll film original negatives. This includes information transfer, tonal quality, resolution transfer and stability. The duplicating films evaluated [redacted] The overall results show that there is statistically no significant difference between the [redacted] first by raw score. The remaining films rank in the following order: [redacted] These films are significantly poorer than both of the [redacted] film types.

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The NPIC test was subdivided into three parts: Photointerpretation Performance Analysis, Technical Analysis, and Mensuration Analysis. The test was high volume, production oriented; i.e., no attempt was made to examine any special applications of these films.

The films and equipment used represent the state-of-the-art in processing and materials as of January 1971. The imagery used was selected from operational missions. All dupe films were exposed at a normal, +0.2, and -0.2 neutral density exposure level.

I. PHOTOINTERPRETATION PERFORMANCE ANALYSIS

A. Technique and Results

Interpretation of targets was used to determine the photointerpreter's performance on the various duplication films. The overall ranking of the duplicating films by raw score shows that the photointerpreters performed the best when interpreting imagery duplicated [redacted] ranked second, but significante tests show that there was no difference between the two processes. The remaining films [redacted] are significantly poorer than both [redacted] films; however, there is statistically no significant difference between these four film types (Table 1).

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Table 1. Results--PI Performance Test (confirmed answers only)

25X1

	No Significant Difference (α=0.10)	Normalized Raw Score
[redacted]		100.0
		98.4
		89.4
		87.3
		86.7
		83.4

[redacted]
25X1

B. Preliminary Considerations

A paired comparison and the performance test were considered as possible ways to test PI preference. The performance test was selected because a pilot study indicated that there is no difference between the results derived from comparison or performance methods. Also, the performance test is more like the interpreter's task of extracting information from photography than is the comparison test. The performance test took one-half the time of the paired comparison technique and had the additional benefit of reducing the PI reaction to superficial physical film characteristics. For example, the blue color of Free Radical might influence the PI performance in a comparison made but the actual print information content may be identical.

QUESTION

Record each letter in the box and check level of confidence for each letter.

	Letter	Conf	Prob	Poss
a				
b				
c				
d				
e				
f				
g				
h				
i				

NPIC P-3707

FIGURE 1. EXAMPLE OF PERFORMANCE TEST QUESTION

C. Performance Test

The performance test consisted of 38 questions based on aerial scenes. These questions required the photointerpreter to count or identify objects. The questions and imagery used were selected by a photoscientist, a photointerpreter, and a test design consultant. The questions were intended to test the interpreter's ability to extract information imaged at the threshold of detection and/or identification. The original negative was used as a basis for the correct answers.

A Latin Square design was used in the performance test. In using this design, learning effect has been eliminated by arranging the film/exposure combinations so that a PI will see only a given target/question combination once (Table 2).

*Table 2. Latin Square Design**

REPLICATE	P.I.
1	1 2 3 4 5 - - - - - - - - - - - - - - 19
2	20 21 22 23 - - - - - - - - - - - - - - - 38
3	39 40 41 - - - - - - - - - - - - - - - - 57
4	58 59 - - - - - - - - - - - - - - - - - 76
5	77 - - - - - - - - - - - - - - - - - - 95

QUESTION	Film/Exposure Combinations
1	1 2 3 4 5 - - - - - - - - - - - - - - 19
2	2 3 4 5 - - - - - - - - - - - - - - -
3	3 4 5 - - - - - - - - - - - - - - -
4	4 5 - - - - - - - - - - - - - - -
⋮	5
⋮	⋮
19	19 1 2 3 4 5 - - - - - - - - - - - - 1
20	1 2 3 4 5 - - - - - - - - - - - - 19
21	2 3 4 5 - - - - - - - - - - - -
⋮	3 4 5 - - - - - - - - - - -
⋮	4 5 - - - - - - - - - -
⋮	⋮
38	19 - 1

18 Film/Exposure Combinations + One Control

*The basic design was doubled to provide more data for each film/exposure combination.

25X1

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[redacted]

Five groups of 19 photointerpreters were used in this evaluation. This provided five replicates for each question on each film/exposure combination.

Viewing conditions were not rigidly controlled. The interpreters used [redacted] light tables. [redacted] microscopes mounted on [redacted] The interpreters were allowed to adjust both viewing magnification and light level.

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Scoring of the test varied according to the type of question asked. The identification type question was scored as one for a correct or zero for an incorrect answer. The count type question was scored as follows: If the indicated count was equal to or less than the correct count, the indicated count was used as the score. If the indicated count was more than the correct count, the excess was subtracted from the correct count and that value used as the score. If this value was negative, zero was used as the score. Each answer was associated with a confidence level–confirmed, probable, or possible. For example, if ten trucks were imaged and the interpreter indicated 7 confirmed, 2 probable, and 1 possible, he was scored as follows: seven points in the confirmed category and 10 points for confirmed plus probable plus possible category. However, the results shown for this test are based on confirmed category answers only.

A one factor analysis of variance and the Duncan New Multiple Range Test were used to analyze the data. A score for each film/exposure combination was based on all 38 questions. The analysis of variance indicated film/exposure to be a significant factor. The range test was then used to show which films were significantly different. In order to rank emulsion type using the range test, the average over each exposure within a given emulsion was calculated and the variances of each exposure pooled. The five replicates (five groups of interpreters) provided the error term to be used in the range test.

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25X1

II. TECHNICAL ANALYSIS

A. Technique and Results

The quality of the subject duplicate materials was evaluated by two methods, a paired comparison and resolution target analysis. Both these tests show [redacted] to be the best duplicating product.

B. Paired Comparison Test

The Paired comparison Test was conducted to analyze the subjective impression of quality with respect to each emulsion. The results show that the [redacted] films are significantly better [redacted] And, there is no difference between [redacted] significantly poorer than all the other films (see Table 3).

Table 3. Results--Full Paired Comparison Test

	No Significant Difference (α=0.10)	Raw Score	Normalized Score
[redacted]		116	100.0
		110	94.9
		101	86.8
		96	83.0
		93	80.5
		81	70.1

The paired comparison technique is an excellent subjective method for distinguishing small differences in image quality. Three scenes were chosen which were judged to be free from manufacturing defects. This provided 3 sets of 18 chips for comparison. To make the experiment shorter, a preliminary comparison was conducted to determine the best exposure per scene for each emulsion. This reduced the number of comparisons to 3 sets of 6 emulsions. A full paired comparison test was then conducted for these 18 chips.

Five experienced photographic technologists made the comparisons. They were instructed to keep in mind resolution, sharpness, graininess, and tonal quality. All observations were made with an [redacted] Microscope.

The data was statistically analyzed using an Analysis of Variance and the Duncan New Multiple Range Test. First, the ratio

$$R = \frac{N_c}{N_o}$$

was calculated. N_c is the number of times the chip was chosen as superior and N_o is the number of times the chip was presented. This ratio was then converted to a standard score (Z_o) using a cumulative normal distribution table. A positive number P_z was calculated by:

$$P_z = (Z_o \times 10) + 100$$

P_z was then used as the response for each chip (see Appendix E for P_z values).

An analysis of variance showed film type to be a significant factor. The range test was used to determine which film types were significantly different from each other (Table 3).

C. Resolution Analysis

Fifty tri-bar resolution targets were read by nine experienced photoscientists. The targets were read on the original film and on each of the 18 duplicate film/exposure combinations. To assess the duplication potential of each emulsion, an average resolution figure for each observer and film/exposure combination was calculated by averaging over the 50 targets. A three-factor (observer, emulsion, exposure) analysis of variance was used to test for significant factors. All three factors were significant. To test for significance among emulsions, the values for each emulsion were averaged over observers and exposure. The Multiple Range Test was used and the results are shown in Table 4.

Table 4. Multiple Range Test Results

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	No Significant Difference (α = 0.10)	Average Resolution (l/mm)
[redacted]		84.6
		84.3
		79.2
		77.2
		73.9
		70.9

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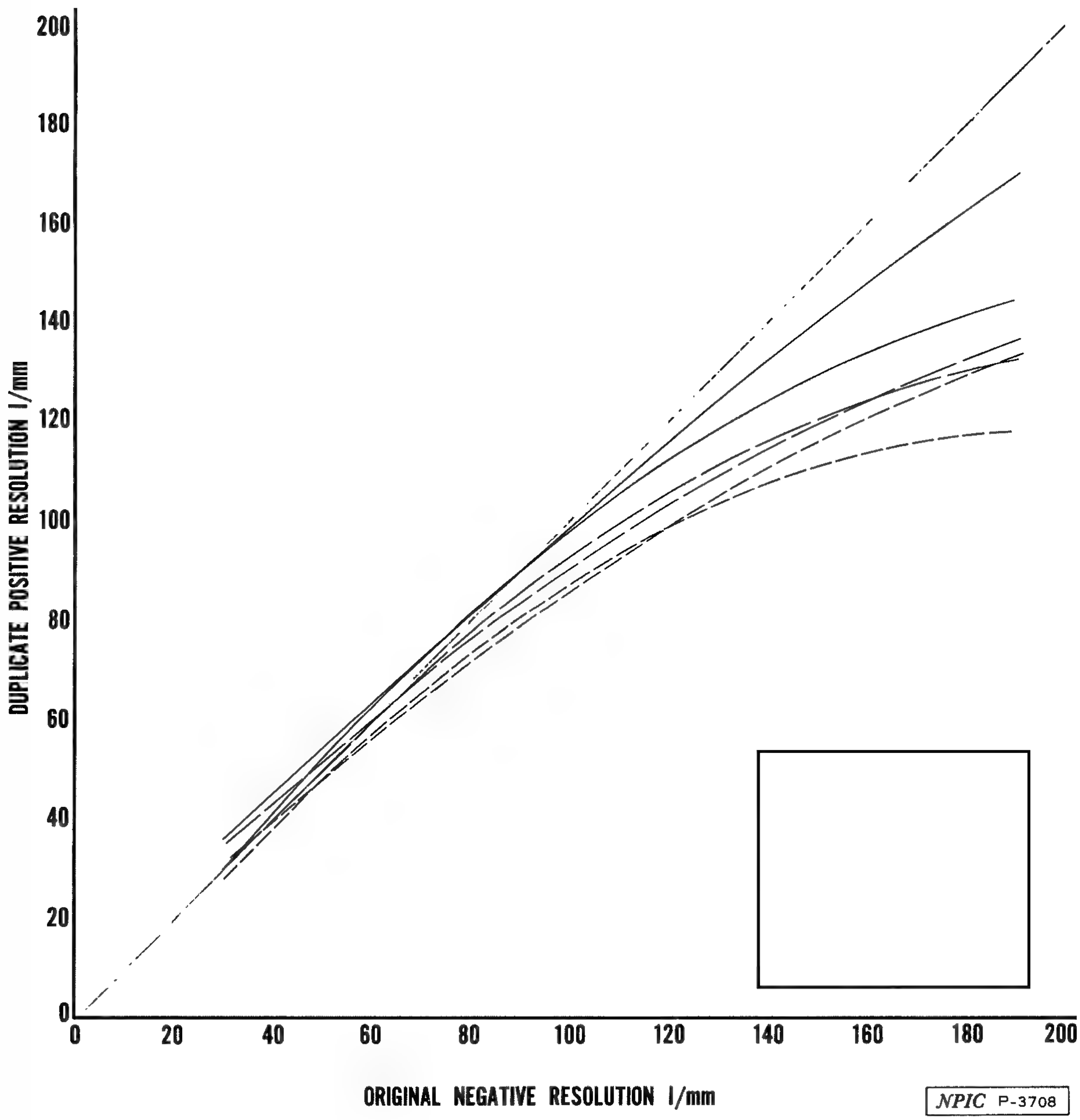
25X1

The [redacted] films are significantly better than the remaining duplicating films and there is no difference between the [redacted] films. Further tests which included the Original Negative (O.N.) readings show that the [redacted] films are not significantly different from the original negative.

Another factor that was examined was the relation between original negative and duplicating film resolution readings. A second order linear regression analysis was performed on each of the duplicating films against the original negative. These curves are shown in Figure 2.



25X1

FIGURE 2. REGRESSION CURVES--O.N. VS D.P.

Ideally, this relation should be a straight line with a slope of 1.00. However, resolutions above 150 1/mm show a greater loss in the reproduction process. This caused the best fit to be of second order. The amount of data above 150 1/mm was very small. Scatter diagrams of the data throughout the whole resolution range and above 150 1/mm are shown in Figures 3 and 4 respectively. There is a trend, however, for a greater resolution loss in [redacted] than that in [redacted] for resolution above 150 1/mm. This is only a trend and is based on only a few data points. More data above 150 1/mm is needed to further assess the duplication potential of these films at higher resolutions.

Four hundred and fifty data points were used to compute the regression lines. That is, nine observers read fifty targets and only the data from the best exposure was used. In Table 5, the amount of variability accounted for by the regression equation is tabulated.

Table 5. Percent of Variability Accounted for by Regression

	Percentage
[redacted]	72.04
	68.95
	69.52
	66.98
	71.46
	71.94

Approximately 70 percent of the variability due to the dupe films as a function of the original negative input is accounted for in regression. The remaining 30 percent of the variability is due to error and/or other untested factors in the regression; for example, targets or observers were not tested for in this portion of the experiment.

Further testing of these film types for resolution transfer is warranted at resolutions greater than 150 l/mm.

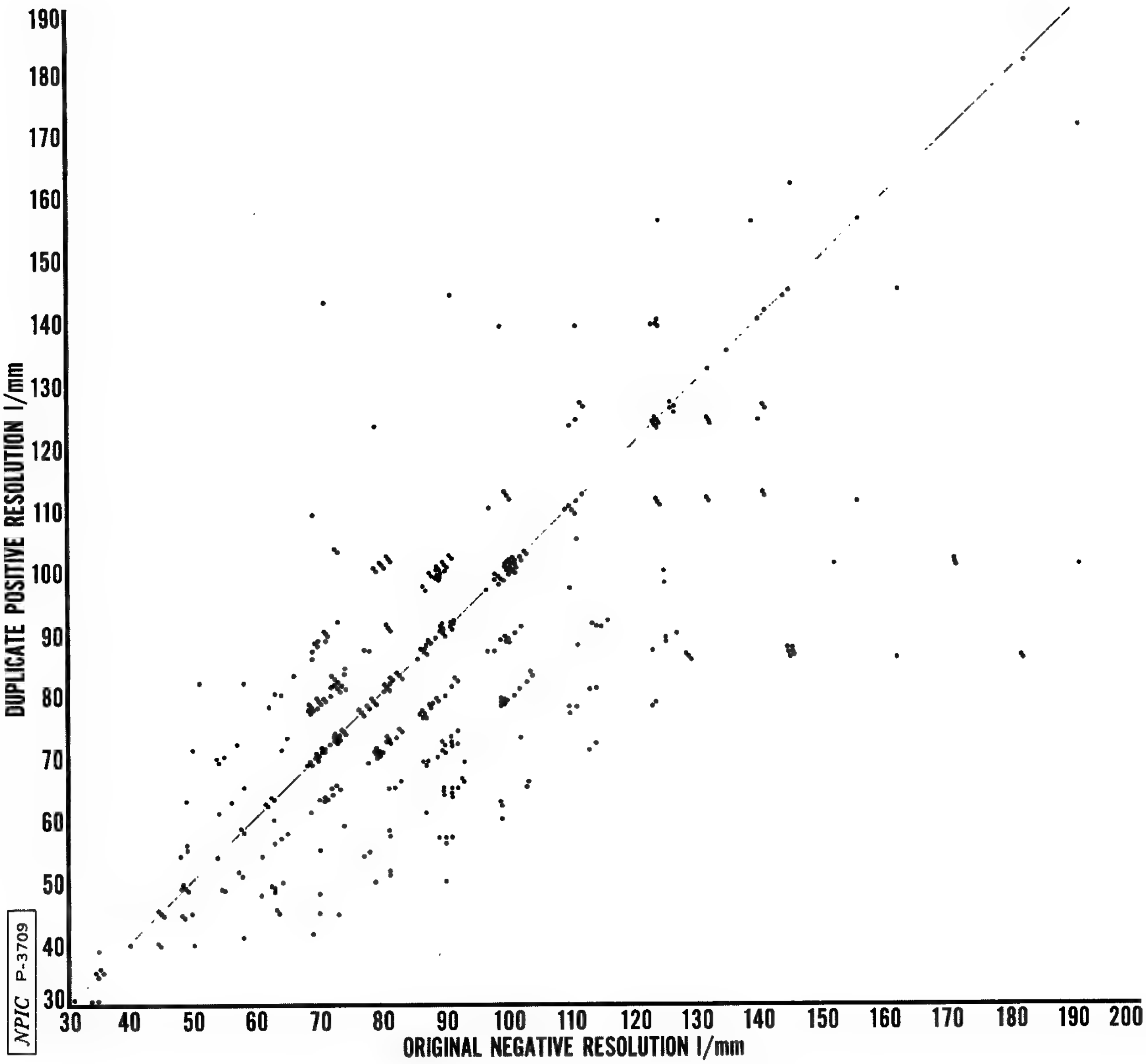


FIGURE 3. TYPICAL SCATTER DIAGRAM

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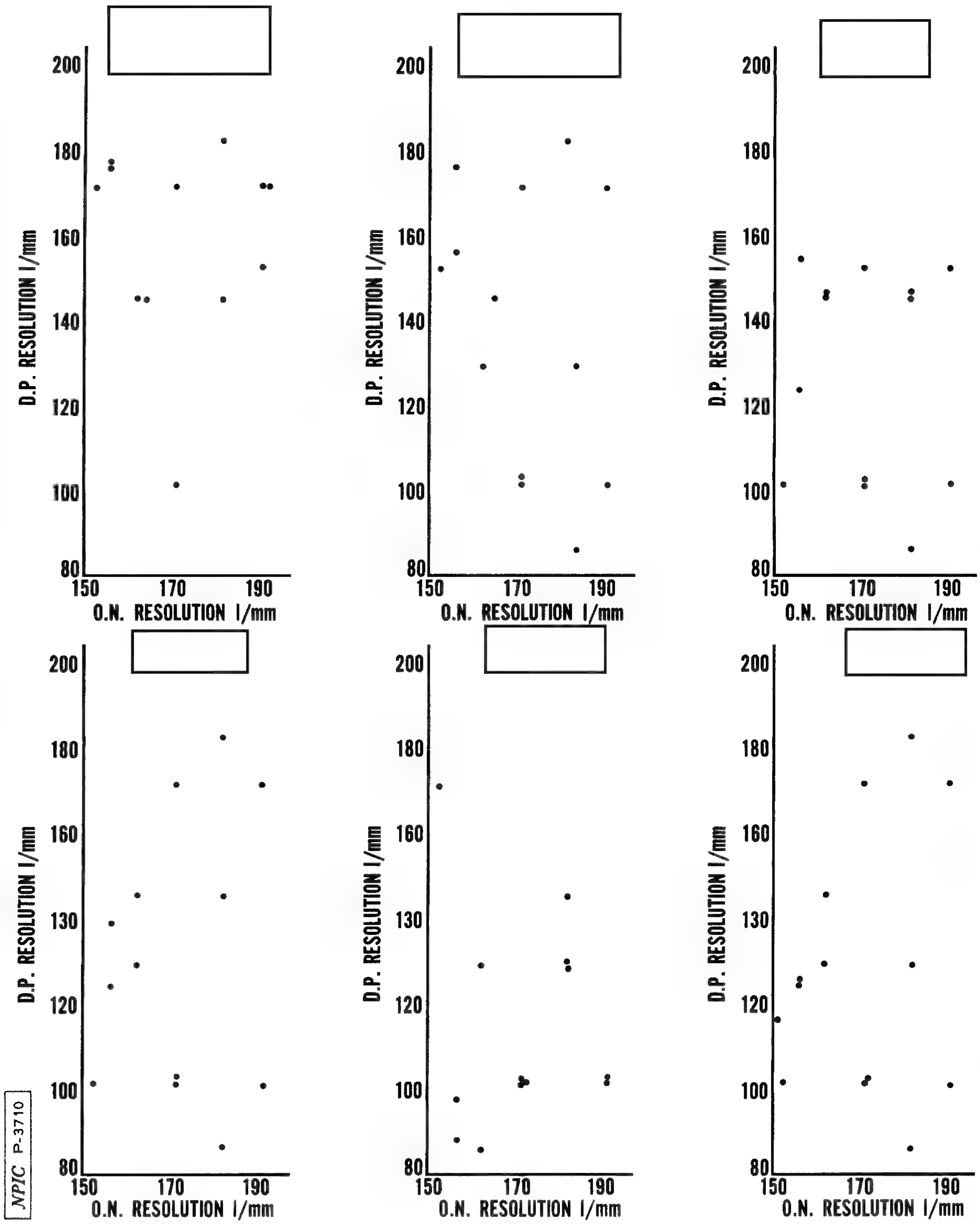

25X1

25X1

FIGURE 4. SCATTER DIAGRAMS, >150 l/mm

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III. MENSURATION ANALYSIS

A. Technique and Results

The mensuration analysis was divided into three parts: Film Stability, Pointing Repeatability, and Image Quality Preference (subjective judgment by photogrammetrists). The overall results show that [redacted] is the best for mensuration. [redacted] are considered acceptable; [redacted] are considered unacceptable mainly due to film/emulsion instability. 25X1 25X1 25X1

All pointings were accomplished by five experienced photogrammetrists using a [redacted] Comparator. A total of 1900 pointings were made. (The points chosen for this test were light-on-light, dark-on-dark, light-on-dark, and dark-on-light). 25X1 25X1

Two points defined distances in each direction--along and across track on the film. Each of the five photogrammetrists replicated each measurement five times to yield a satisfactory estimate of experimental error. All results were evaluated using analyses of variance and range tests.

B. Dimensional Stability

Dimensional stability is defined, in this case, as the difference between measurements of the same object on the original negative and the duplicate positive. The results are listed in Table 6.

Table 6. Results–Stability Test

Along Track Δ from O.N. (μm)		No Sign. Diff. α=0.01)		Across Track Δ from O.N. (μm)
--	[redacted]		[redacted]	--
0.7 (L)				3.4 (S)
2.5 (S)				5.3 (S)
7.1 (S)				6.5 (S)
10.5 (S)				7.5 (S)
24.1 (S)				50.3 (S)
32.6 (L)				126.0 (S)

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(S) = shorter than O.N.
(L) = Longer than O.N.

Since two unique distances were involved, an analysis of variance was done twice. Each time, films were a significant factor. The Duncan New Multiple Range Test was used to test for significance among films. The data used represented the average of the five observations and three exposures (Table 6).

C. Repeatability

Repeatability is defined as the precision of the individual pointings. The results of this test show that [redacted] Dry Silver is significantly poorer than the remaining film types.

25X1

The variance of each point (x and y) for each observer was transformed using common log transformation so that the variances would approximate a normal distribution. The average of the five observers on each chip was then used as the response. An analysis of variance showed that exposure level was not significant; therefore, the responses for each exposure level were averaged and used as the response for the emulsion. The films were then tested for significant difference using the Neuman-Keuls sequential range test (Table 7).

Table 7. Results–Repeatability Test

	Variance (m^2)	No Significant Difference ($\alpha = 0.01$)
[redacted]	0.85	
	0.96	
	1.12	
	1.43	
	1.60	
	2.05	

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[redacted]

D. Image Quality Estimate

Image quality is defined as the qualitative impressions of the photogrammetrist while viewing the imagery in the comparator. This judgment is primarily based on the ease with which the photogrammetrist can observe a given point. The results show that [redacted] ranked first (Table 8).

The scores are totals of each individual's evaluation. The scoring was based on the following: excellent--4, good--3, fair--2, and poor--1.

Table 8. Results--Image Quality

	Score
[redacted]	190
	186
	172
	143
	138

Perfect score: 240

[redacted]

CONCLUSIONS

Based on all three analyses, the films can be ranked from best to worst [redacted] with no significant difference established [redacted] These films are significantly different [redacted] is significantly poorer than the remaining films.

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These analyses were designed to assess overall duplicating quality. No attempt was made to test for special applications, such as high contrast printing and/or highlight or shadow detail enhancement. The films were judged for their ability to duplicate the original negative material in a large volume, roll film production operation.

Further data should be collected and analyzed for testing the duplication of original negatives with resolutions greater than 150 l/mm .

Appendix A. General References

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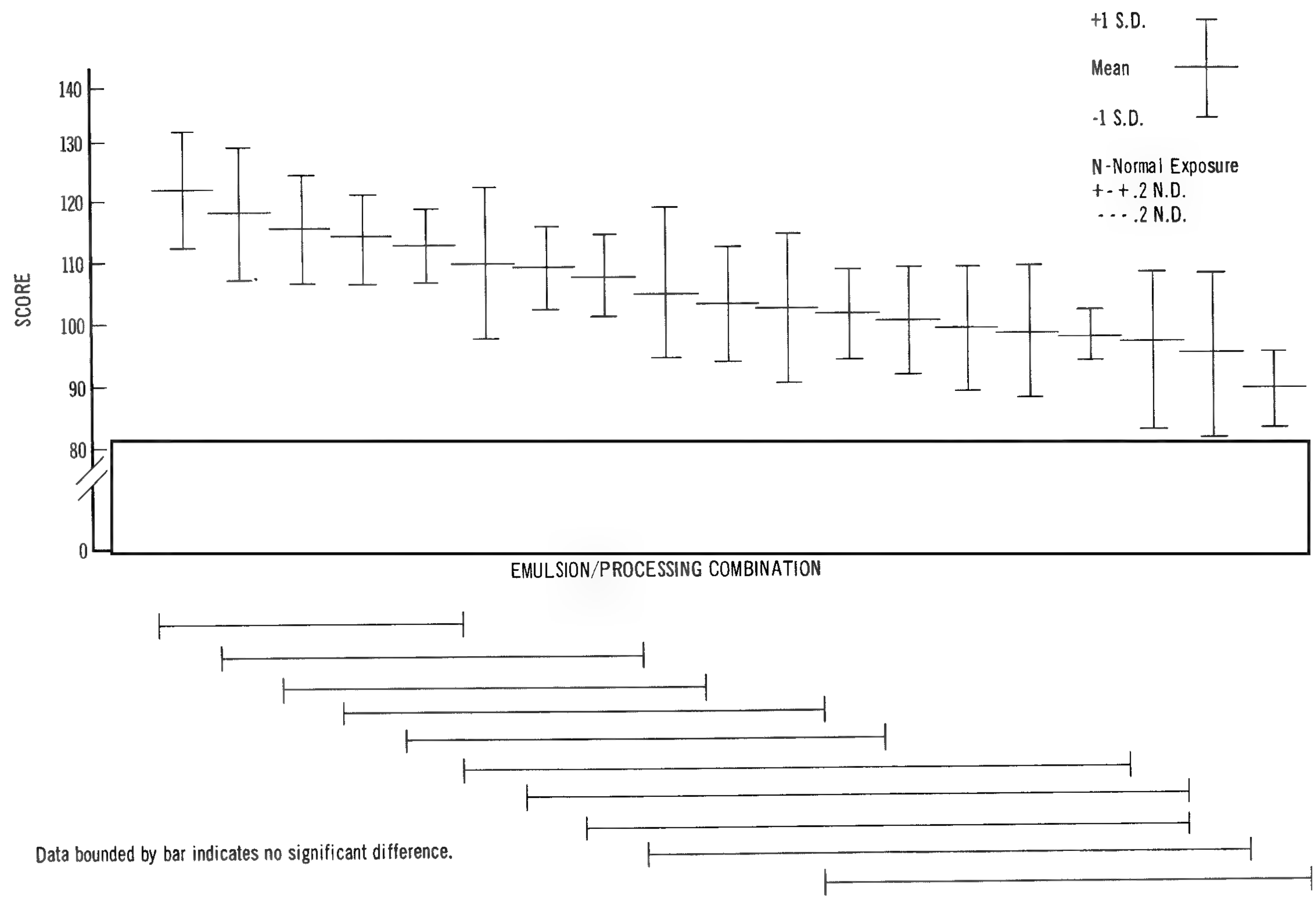

DUNCAN'S MULTIPLE RANGE TEST (0.10 LEVEL), CONFIRMED SCORES ONLY.

APPENDIX B. DIFFERENCE BETWEEN EMULSION/EXPOSURE–PI PERFORMANCE TEST

APPENDIX C. PRELIMINARY COMPARISON DATA--TECHNICAL ANALYSIS

Ranking of Exposure

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Target No.	Exposure	Rank Observer 1	2	3	4	5	Total
20	+.2 N.D.	3	3	3	3	3	15
	Normal	2	2	2	2	2	10
	-.2 N.D.	1	1	1	1	1	5*
33	+2 N.D.	2	3	3	3	3	14
	Normal	3	2	1	2	2	10
	-.2 N.D.	1	1	2	1	1	6*
40	+2 N.D.	3	2	3	3	3	14
	Normal	1	3	1	2	2	9
	-.2 N.D.	2	1	2	1	1	7*
20	+.2 N.D.	3	3	3	3	3	15
	Normal	2	2	1	1	2	8
	-.2 N.D.	1	1	2	2	1	7*
33	+.2 N.D.	2	3	3	2	3	13
	Normal	3	2	2	1	2	10
	-.2 N.D.	1	1	1	3	1	7*
40	+.2 N.D.	3	3	1	2	3	12
	Normal	2	2	2	1	2	9
	-.2 N.D.	1	1	3	3	1	9*+
20	+.2 N.D.	3	3	3	3	3	15
	Normal	2	2	1	1	2	8
	-.2 N.D.	1	1	2	2	1	7*
33	+.2 N.D.	3	3	2	3	3	14
	Normal	2	2	1	2	2	9
	-.2 N.D.	1	1	3	1	1	7*
40	+.2 N.D.	2	3	2	3	3	13
	Normal	3	2	1	2	2	10
	-.2 N.D.	1	1	3	1	1	7*
20	+.2 N.D.	2	3	3	3	3	14
	Normal	1	1	1	1	2	6*
	-.2 N.D.	3	2	2	2	1	10
33	+.2 N.D.	2	3	3	3	3	14
	Normal	3	2	2	2	2	11
	-.2 N.D.	1	1	1	1	1	5*
40	+.2 N.D.	2	3	3	3	3	14
	Normal	3	2	2	2	1	10
	-.2 N.D.	1	1	1	1	2	6*

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Ranking of Exposure (Continued)

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Target No.	Exposure	Rank Observer 1	2	3	4	5	Total
20	+.2 N.D.	3	3	3	3	3	15
	Normal	1	2	1	1	2	7*
	-.2 N.D.	2	1	2	2	1	8
33	+.2 N.D.	2	3	3	3	3	14
	Normal	1	2	1	1	2	7*
	-.2 N.D.	3	1	2	2	1	9
40	+.2 N.D.	3	3	3	3	3	15
	Normal	2	2	2	1	2	9
	-.2 N.D.	1	1	1	2	1	6*
20	+.2 N.D.	2	3	2	3	2	12
	Normal	3	2	3	2	3	13
	-.2 N.D.	1	1	1	1	1	5*
33	+.2 N.D.	3	3	2	3	3	14
	Normal	2	2	3	2	2	11
	-.2 N.D.	1	1	1	1	1	5*
40	+.2 N.D.	3	3	2	3	3	14
	Normal	2	2	3	2	2	11
	-.2 N.D.	1	1	1	1	1	5*

*Select for Paired Comparison.
+Tie score was broken by two additional observers.

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APPENDIX D. RATIO TO Z SCORE--PAIRED COMPARISON TEST, TECHNICAL ANALYSIS

Ratio	Z Score	Z Transformed [(Z x 10) + 100]
0/5	-2.33	76.7
1/5	-0.84	91.6
2/5	-0.25	97.5
3/5	+0.25	102.5
4/5	+0.84	108.4
5/5	+2.33	123.3

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APPENDIX E. PAIRED COMPARISON Z SCORE -- TECHNICAL ANALYSIS

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Exposure	Target No.	Code	Observer 1	2	3	4	5
-.2 N.D.	20	11	102.5	102.5	91.6	97.5	102.5
-.2 N.D.	33	12	102.5	97.5	108.4	97.5	102.5
-.2 N.D.	40	13	102.5	102.5	102.5	97.5	102.5
-.2 N.D.	20	21	123.3	102.5	123.3	108.4	123.3
-.2 N.D.	33	22	123.3	102.5	123.3	123.3	123.3
-.2 N.D.	40	23	123.3	102.5	108.4	108.4	123.3
-.2 N.D.	20	31	108.4	123.3	108.4	108.4	108.4
-.2 N.D.	33	32	108.4	108.4	102.5	97.5	108.4
-.2 N.D.	40	33	108.4	108.4	123.3	123.3	108.4
Normal	20	41	97.5	102.5	76.7	97.5	91.4
-.2 N.D.	33	42	97.5	123.3	91.6	102.5	91.4
-.2 N.D.	40	43	97.5	102.5	91.6	91.6	91.4
-.2 N.D.	20	51	76.7	91.6	97.5	76.7	76.7
-.2 N.D.	33	52	76.7	91.6	76.7	76.7	76.7
-.2 N.D.	40	53	76.7	97.5	76.7	76.7	76.7
Normal	20	61	91.6	76.7	102.5	102.5	97.5
Normal	33	62	91.6	76.7	97.5	102.5	97.5
-.2 N.D.	40	63	91.6	76.7	97.5	102.5	97.5

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APPENDIX F. DIMENSIONAL STABILITY DATA--MENSURATION ANALYSIS

Mensuration Distance

Distance 1 (Across Track) Exp.	Mean (μm)	Variance (μm^2)	Distance 2 (Along Track) Exp.	Mean (μm)	Variance (μm^2)
	13668.7	1.98	-	14270.8	5.18
N	13666.4	3.03	+	14270.4	2.33
N	13665.0	3.88	N	14269.2	2.33
N	13665.0	0.64	N	14228.6	0.77
+	13664.9	1.71	+	14227.8	2.37
-	13664.4	2.57		14226.6	4.23
N	13663.8	1.64	-	14225.4	4.59
-	13663.4	4.03	-	14224.4	5.29
-	13663.1	2.31	+	14224.2	3.32
+	13662.1	5.48	N	14223.7	1.66
+	13661.8	1.21	+	14220.5	3.74
-	13661.0	0.76	N	14219.4	0.61
+	13655.3	2.59	-	14218.5	5.55
-	13623.9	3.25	N	14218.4	1.72
N	13623.8	2.57	-	14216.4	3.29
+	13607.5	4.65	+	14213.4	2.01
-	13545.0	10.25	N	14210.1	2.60
N	13542.9	6.90	+	14203.9	0.42
+	13540.2	4.10	-	14193.6	1.15

+ = +.2 Neutral Density
N = Normal Neutral Density
- = -.2 Neutral Density

APPENDIX G. REPEATABILITY DATA AND RANKING--MENSURATION ANALYSIS

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Exp.	Variance (m^2)
-	0.76
N	0.76
-	0.78
+	0.83
N	0.94
N	0.95
-	1.02
+	1.18
N	1.24
-	1.25
-	1.26
-	1.34
+	1.58
+	1.65
+	1.82
N	1.89
N	2.37
+	2.42

+ = +.2 Neutral Density
N = Normal Neutral Density
- = -.2 Neutral Density

APPENDIX H. IMAGE QUALITY SCORES*--MENSURATION ANALYSIS

25X1

[redacted]	Exp.	Score
	N	71
	N	67
	N	67
	-	66
	+	62
	-	61
	-	55
	+	55
	N	55
	+	53
	-	50
	-	48
	N	46
	-	46
	N	45
	+	42
	+	40
	+	38

*The data used for comparing the films is the sum of the scores for each exposure per film type.

25X1

Approved For Release 2003/05/14 : CIA-RDP78B04560A007300010012-5